DAMES & MOORE

CONSULTANTS IN THE ENVIRONMENTAL AND APPLIED EARTH SCIENCES

September 30, 1980

Shell Oil Company
Post Office Box 262
Wood River, Illinois 62095

Attention: Mr. J. I. Celis, Jr.
Project Manager

Gentlemen:

Six copies of our report, "Phase I - Waste Management Survey and Preliminary Site Selection For Ultimate Disposal Facility, Shell Oil Company, Wood River, Illinois" are herewith submitted.

The investigation included a description of the plant and waste management facilities, waste streams, site conditions and site selection for the new ultimate waste disposal facility. Recommendations are included in the report for Phase II of the study.

It has been a pleasure to be of service to you on the Phase I studies, and we look forward to working with you on the Phase II study. If you have any questions you may wish to discuss regarding our study or its conclusions please feel free to contact us.

Very truly yours,

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PHASE I
WASTE MANAGEMENT SURVEY
AND PRELIMINARY SITE SELECTION
FOR ULTIMATE DISPOSAL FACILITY
SHELL OIL COMPANY, WOOD RIVER, ILLINOIS

Dames & Moore

Job No. 00216-222-07
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TABLE OF CONTENTS

Page

SUMMARY 1

1.0 INTRODUCTION. 4

2.0 WASTE MANAGEMENT SURVEY 6

2.1 PLANT FACILITIES AND PROCESSES 6

2.2 WASTE STREAMS AND SOURCES. 6

2.3 WASTE MANAGEMENT FACILITIES. 8

2.3.1 OIL RECOVERY FACILITIES 8

2.3.1.1 API SEPARATORS. 9

2.3.1.2 WORK TANKS. 9

2.3.1.3 CENTRIFUGE. 9

2.3.2 SECONDARY OIL REMOVAL FACILITIES. 10

2.3.3 BIOLOGICAL TREATMENT SYSTEM 10

2.3.4 ON-SITE STORAGE-TREATMENT-DISPOSAL UNITS. 11

2.3.4.1 SITES 1 AND 2- NEUTRALIZATION POND 12

2.3.4.2 SITE 3 - SOLID WASTE LANDFILL 13

2.3.4.3 SITE 4 - DUMPSTER STAGING AREAS . . . 13

2.3.4.4 SITE 5 - OILY SLUDGE LAGOON 13

2.3.4.5 SITE 6 - CONTAMINATED SOLIDS LANDFILL. 14

2.3.4.6 SITE 7 - WASTE PILES. 14

2.3.4.7 SITE 8 - ASPHALT WASTE IMPOUNDMENT. . 15

2.3.4.8 SITE 9 - CRUDE TANK BOTTOMS POND (SOUTHWEST PROPERTY) 15

2.3.4.9 SITE 10- SOLID WASTE BASIN. 15

2.3.4.10 NORTH PONDS 16

2.3.4.11 STORM WATER RETENTION BASIN AND INLET DITCH SYSTEM. 16

2.3.4.12 SMITH LAKE. 17

2.3.4.13 OLD TANNERY SITE. 17

TABLE OF CONTENTS (continued)

		Page
3.0	SITE CONDITIONS	18
3.1	GEOLOGY AND SOILS	18
3.1.1	GLACIAL OUTWASH DEPOSITS	18
3.1.2	CAHOKIA ALLUVIUM	19
3.1.3	BEDROCK - STRUCTURAL GEOLOGY AND SEISMOLOGY	20
3.2	GROUND-WATER HYDROLOGY	21
3.2.1	GENERAL	21
3.2.2	GROUND-WATER MOVEMENT	21
3.2.3	PERMEABILITY	23
3.2.4	GROUND-WATER QUALITY	23
3.3	SITE TOPOGRAPHY AND SURFACE-WATER HYDROLOGY	23
3.4	WETLANDS AND CRITICAL HABITAT	25
3.4.1	ENDANGERED OR THREATENED SPECIES	25
3.4.2	WETLANDS	25
3.5	CLIMATOLOGY	25
4.0	PRELIMINARY SITE SELECTION FOR THE NEW DISPOSAL FACILITY	28
4.1	CRITERIA OF SITE SELECTION	28
4.1.1	CRITERIA	28
4.1.2	GEOLOGY AND SOIL TYPE	30
4.1.3	GROUND-WATER HYDROLOGY	30
4.1.4	PROXIMITY TO POPULATED AREAS	31
4.1.5	TOPOGRAPHY	32
4.1.6	FLOOD HAZARD AREAS	32
4.1.7	WETLANDS AND CRITICAL HABITATS	32
4.1.8	DISTANCE FROM THE PLANT	33

TABLE OF CONTENTS (continued)

	Page
4.2 SITE RATINGS.	33
4.2.1 SITE RATING SCHEME.	33
4.2.2 POTENTIAL SITE 1.	34
4.2.3 POTENTIAL SITE 2.	34
4.2.4 POTENTIAL SITE 3.	35
4.2.5 POTENTIAL SITE 4.	36
4.2.6 CONCLUSIONS	36
5.0 RECOMMENDATIONS FOR PHASE II PROGRAMS	37
5.1 OBJECTIVES AND CONCEPTUAL APPROACH	37
5.2 INITIAL INVESTIGATION FOR NEW SITES.	38
5.2.1 DRILLING OF BORINGS AND INSTALLATION OF PIEZOMETERS.	38
5.2.2 SAMPLING AND TESTING OF SOIL SAMPLES.	39
5.2.3 IN-SITU PERMEABILITY TESTS.	40
5.2.4 INVESTIGATION OF BORROW SOURCES OF CLAY LINER MATERIALS	40
5.3 DEVELOPMENT OF A GENERIC CLOSURE AND POST-CLOSURE PLAN.	41
5.4. PREPARATION OF TOPOGRAPHIC MAP	43
5.5 ADDITIONAL SITE INVESTIGATION.	43
5.6 OTHER PHASE II TASKS	44
5.6.1 ASSISTING IN PREPARING PERMIT APPLICATION DOCUMENTS	44
5.6.2 CONSULTATION REGARDING WASTE MANAGEMENT ALTERNATIVES.	46
6.0 REFERENCES.	47

LIST OF TABLES

NUMBER	TITLE
1	DESCRIPTION OF HAZARDOUS WASTE
2	WASTE STORAGE, TREATMENT AND DISPOSAL UNITS
3	EVALUATION OF SITES

LIST OF FIGURES

NUMBER	TITLE
1	SHELL OIL COMPANY - WOOD RIVER REFINERY LOCATION MAP
2	WASTEWATER TREATMENT SYSTEM
3	LOCATION OF WASTE MANAGEMENT FACILITIES AND SURFACE FEATURES
4	SURFICIAL DEPOSITS IN THE VICINITY OF THE REFINERY
5	WATER TABLE CONTOUR MAP - MAY 5, 1980
6	SURFACE-WATER HYDROLOGY IN THE VICINITY OF THE REFINERY
7	TERMINAL SURFACE STORAGE IMPOUNDMENT - GEOLOGIC CONDITIONS EXISTING
8	LANDFILL OR TERMINAL SURFACE STORAGE IMPOUNDMENT A
9	LANDFILL OR TERMINAL SURFACE STORAGE IMPOUNDMENT B

SUMMARY

PHASE I - WASTE MANAGEMENT SURVEY AND PRELIMINARY SITE SELECTION FOR ULTIMATE DISPOSAL FACILITY SHELL OIL COMPANY, WOOD RIVER, ILLINOIS

In the Phase I studies, existing data related to site conditions and waste management facilities were throughly reviewed. Based on the results of our survey, it is our opinion that no major site-related factors exist that would prevent the construction and operation of an ultimate, hazardous waste surface impoundment facility. In addition, the review indicated that for most of the existing waste management facilities there is a lack of sufficient data for evaluation regarding regulatory compliance and necessary upgrading.

Most of the main property at the Shell Refinery, and the north property west of the present disposal facilities, are underlain by glacial outwash deposits of the Mackinaw Member of the Henry Formation. These deposits extend from the surface to bedrock. The remaining portion of the Shell site is underlain by variable thicknesses of Cahokia alluvium, which in turn is generally underlain by outwash deposits overlying bedrock.

00216-222-07

The proposed siting criteria contained in the regulations of RCRA specify that a hazardous waste disposal facility cannot be sited in an active fault zone. Based on published data, several earthquake epicenters have been located in the site area but no active faults have been identified at the site.

Ground water in the Hartford-Roxana-Wood River area appears to occur primarily under water table conditions, however, semi-confined conditions may occur locally where the fine grained alluvial silts and clays of the Cahokia alluvium overlie coarse grained alluvium and glacial outwash deposits. Pumping performed by several on-site wells has lowered the water table, and altered its shape into a cone of depression. Available water table maps suggest that along the eastern edge of the property the soil transmissivity is relatively low in comparison to the more western areas.

Most of Shell's property lies within an area of minimal flooding. Based upon available data, the northeastern and eastern portions of Shell's north property lie within the 100 year flood boundary. Some of this area may also lie within a 500 year flood zone. If levees are built on the Missouri side of the Mississippi River, flood levels in Illinois may be affected. It is possible that the extent and elevations of these flood hazard areas may be reduced by construction of flood control structures in the city of Wood River.

There is no recorded occurrence of state or federally designated endangered or threatened species near the city of Wood River. However, there are several wetlands located within the Shell Oil property near Smith Lake, some of which are natural while others appear to have been man-made or substantially modified by man. Site reconnaissance would likely be necessary to further define existing conditions.

In the Phase I program, preliminary geological, hydrological, and ecological studies were performed in order to select a site on the Shell Oil Refinery property for the development of an ultimate surface storage impoundment facility. The construction and placement of this facility must meet all applicable state and federal requirements as originally promulgated under the Resource Conservation and Recovery Act (RCRA). A number of criteria were used to determine the suitability of potential sites. These criteria included geology and soil type, ground water hydrology, proximity to populated areas, topography, and distance from the plant. The selection process was also guided by the rules and regulations of RCRA as proposed on December 18, 1979.

Our preliminary study identified two potential sites that are most obviously worthy of further site selection consideration. These sites are located on the north property, north of the tank farm, and on the east property, east of crude tank bottoms.

Based on the results of Phase I studies, a more detailed investigation to evaluate the potential sites is being proposed. The major objective of the Phase II studies will be to obtain site specific (soils and hydrologic) data at the proposed new facility sites. These data will be utilized to develop conceptual designs, and compare costs for various alternatives at potentially feasible sites. In addition, a generic closure and post-closure plan will be prepared for the existing waste management units. Furthermore, Dames & Moore will assist, if required, in the preparation of documents for permit applications, and will be available for consultation regarding compliance with the Interim Status Standards of RCRA.

PHASE I
WASTE MANAGEMENT SURVEY
AND PRELIMINARY SITE SELECTION
FOR ULTIMATE DISPOSAL FACILITY
SHELL OIL COMPANY, WOOD RIVER, ILLINOIS

1.0 INTRODUCTION

This report presents the results of Phase I of the waste management facility survey performed for the Shell Oil Company Refinery located in Wood River, Madison County, Illinois. The site is located on the broad floodplain and terrace remnants of the Mississippi River (Figure 1, Shell Oil Company Wood River Refinery Location Map).

The Shell Oil Company Wood River Refinery consists of five main blocks of property (shown on Figure 1, Location Map) these include:

1. The North Property, bounded by the town of Roxana and city of Wood River on the west, has three land use types. The north portion is leased out as farmland, the southwest portion consists of storage tanks and the east portion is where most of the current and past waste management units are located.

2. The Main Property, bounded by Hawthorne Street to the south, is where the main refinery process units are located.

3. The Southwest Property has crude storage tanks and a surface impoundment for recoverable crude tank bottoms.

4. The West Property is where the main components of the wastewater treatment system are located.

5. The Riverfront Property, west of Highway 3, has docking facilities and the wastewater treatment polishing lagoons.

The overall objective of the waste management facility study is to perform necessary engineering services in order to assist Shell Oil Company in the development of an on-site, ultimate surface impoundment facility at Shell Oil's Wood River Refinery. This facility will be specifically designed to meet applicable state and federal requirements as promulgated under the Resource Conservation and Recovery Act (RCRA) of 1976.

The purpose of the Phase I study was to perform a general waste management survey of current practices, and to conduct a preliminary site selection evaluation for the new ultimate disposal facility. Specifically, the following tasks were performed during the Phase I study:

1. A waste management survey, including a review of waste streams and existing waste management facilities;

2. Review of site conditions at the Wood River Refinery, including geology and soils, ground-water hydrology, site topography and surface-water hydrology, wetlands and critical habitats, and climatology;

3. Preliminary site selection for the proposed new, on-site disposal facility; and

4. Recommendations for Phase II programs.

The results of the Phase I study are discussed in the text of this report.

The primary objective of the future Phase II investigation will be to obtain site specific data to use in the conceptual design of the proposed new disposal facility. Furthermore, Dames & Moore will assist (at Shell Oil's request) in the preparation of documents for permit applications, and be available for consultation regarding compliance with the RCRA Interim Status Standards. Phase III and IV of the proposed study will be more specifically related to detailed design, necessary permitting, and construction of these waste management facilities.

2.0 WASTE MANAGEMENT SURVEY

2.1 PLANT FACILITIES AND PROCESSES

The principal products of the Wood River refinery include motor gasoline and other hydrocarbon fuel liquids, lubricating oils, asphalt, fuel gas, and some speciality hydrocarbon products. In addition, the sulfur removed from the crude oil during the refining process is recovered as sulfur and also sold as a product. Some sulfur is used by the acid plant to manufacture sulfuric acid. A portion of the acid is used within the refinery processes, with the excess acid sold as a product. Benzene is extracted from process streams by a benzene extraction unit (BEU), producing pharmaceutical grade benzene. Currently, propylene from the refinery is used to manufacture isopropyl alcohol which is further treated to produce acetone. Also being produced is tertiary-amylene, a precursor for the manufacture of rubber.

2.2 WASTE STREAMS AND SOURCES

Refinery wastes are generated by several generic sources. Refineries generate a large volume of oily water through the processing operations. The Shell Oil-Wood River Refinery extensively treats this oily water to recover as much oil as possible, then further treats the water to remove sufficient pollutants to allow discharge to the Mississippi River. The resultant wastewater streams include American Petroleum Institute (API) Separator bottom sludge, Dissolved Air Floatation (DAF) float and bottoms sludge, slop oil emulsion, centrifuge bottoms and biological treatment sludge.

Another generic waste source is sludges and wastewater generated by plant utilities. These waste streams include spent water softening lime sludge, boiler blowdown, and cooling tower bottoms sludge.

Tank bottoms sludges are also generated through refinery operation. This waste stream is generated whenever a tank is completely cleaned out for repair, maintenance or modification. The character and amount of sludge generated depends on the material previously stored in the tank.

The refinery processes also generate other waste streams. These include acid neutralization sludge, and spent catalysts, filters, clays, driers, and phenolic sludges.

General cleanup, maintenance and construction, and spill cleanup activities produce other wastes. These include trash, waste construction materials, oil contaminated soil and sand, and sludges from various process equipment (heat exchangers, process vessels, etc.). The plant oily water sewer system requires periodic cleanout, also generating a waste sludge.

Some of these waste streams, may be specifically listed by RCRA as hazardous wastes or classified as RCRA hazardous wastes by their physical-chemical characteristics, some may be classified as Illinois Environmental Protection Agency (IEPA) Special Wastes, and the remainder are expected to be non-hazardous wastes.

Table 1 lists an inventory of known and potentially hazardous wastes under RCRA. These data were reproduced from information provided by Shell Oil.

2.3 WASTE MANAGEMENT FACILITIES

The Shell Oil Company waste management facilities at Wood River, Illinois, presently include systems for the recovery of oil from wastewater, systems for the treatment of wastewater, and on-site units for the treatment-storage-disposal of sludges and other solid wastes. The locations of the systems and units described in this section are shown with respect to the refinery facilities on Figure 3. Some hazardous materials, such as leaded and phenolic wastes are currently disposed off-site to approved hazardous waste disposal sites. Some by-product materials are transported to outside vendors for material recovery, and some non-hazardous solid wastes are removed to a municipal landfill. Table 2 describes existing, on-site waste storage, treatment and disposal units, with comments regarding their likely regulatory status and known current and future plans.

A management system established in July of 1979 designated shift foremen who determine waste disposition. Drivers are instructed to contact the foreman, who classifies the material and directs the load to one of the on-site disposal units.

2.3.1 Oil Recovery Facilities

Wastewaters are collected from the refinery process area for oil recovery and treatment. Wastewaters from process areas generally are contact process waters or contaminated noncontact streams, and are usually collected in wastewater sumps located within process areas. Typically, gravity flow or pumps transfer the wastewater from sumps into the plant process wastewater sewer system. Figure 2 is a schematic flow diagram for the overall wastewater treatment system.

2.3.1.1 API Separators

The oily process wastewater collected by the sewer system undergoes treatment by a number of oil separators and two API Separators, Box 11 and Master Box. These units allow gravitational oil-water phase separation in a basin with an oil skimmer, baffle, and wier. Slop oil is collected from the liquid surface in all these API Separators with a surface skimmer and is pumped directly to work tanks. The effluent wastewater is separated from the slop oil layer by an underflow baffle and overflow wier. Effluent gravitates from the API Separator Master Box to the Aeration Basin, where it is mixed with other waste streams for further treatment.

2.3.1.2 Work Tanks

The Work Tanks are steel storage tanks equipped with heaters. The water-oil emulsion phase of the slop oil is treated here with heat and left for a detention time in order to break the emulsion and release the oil. The recovered oil phase is pumped from the Work Tanks for reprocessing in the refinery crude unit. The separated water phase is drained to the oily process sewer. The remaining unbroken emulsion is normally pumped to the Centrifuge Feed Tank, however, if the emulsion is judged to be unrecoverable it is pumped to the Slop Oil Emulsion Tank for storage until it is sold to an outside vendor for recovery.

2.3.1.3 Centrifuge

The Centrifuge is fed slop oil emulsion from the Centrifuge Feed Tank. The resulting recovered oil is eventually processed in the crude unit. The remaining sludge is pumped to the Solid Waste Basin (Site 10) for disposal.

2.3.2 Secondary Oil Removal Facilities

The water phase effluents from the Master Box, API Separator is piped to the Aeration Basin for further treatment to remove oil before ultimate discharge. In the Aeration Basin, plant sanitary sewage and spent lime sludge from water softening are mixed by aeration with the oily water effluents. The oil and other materials are sorbed on the lime sludge, and the lime sludge kills fecal coliform bacteria.

The Aeration Basin discharges the mixture of process water, lime sludge, and sanitary sewage first to an API Separator and then to DAF 1. The skimmings, floats, and bottom sludges from these two units consist of oily lime sludge and water. These materials are removed and pumped to the Solid Waste Basin (Site 10) for ultimate disposal. The wastewater effluent from DAF 1 is further treated by the Biological Treatment System before final discharge.

2.3.3 Biological Treatment System

The Biological Treatment System is operated to reduce the biodegradable organic carbon content of the wastewater prior to final discharge. The Biological Treatment System consists of Aerated Pond 1, Trickling Filter Unit, Aerated Pond 2, DAF 2, and the Polishing Lagoons. Effluent from the Polishing Lagoons is discharged to the Mississippi River through a National Pollutant Discharge Elimination System (NPDES) permitted outfall.

Aerated Pond 1 receives the effluent from DAF 1 and serves to equalize flows to the Trickling Filter Unit. The Trickling Filter uses a fixed medium on whose surfaces the biological sludges metabolize and remove the biodegradable organic components from the wastewater. Heavy metals are also removed from the wastewater and enter the bio-sludge phase. Biological sludge growth in the Trickling Filter results in continual sloughing of excess bio-sludge into the Trickling Filter effluent stream.

The Trickling Filter effluent with sloughed bio-sludge is aerated in Pond 2 which is operated as an activated sludge unit. The Pond 2 effluent is clarified by DAF 2, where removed bio-sludge is completely recycled to Pond 2.

The Polishing Lagoons are located on the river side of the flood levees. In the lagoons, effluent from DAF 2 is further treated by algal growth and sedimentation of suspended solids. The lagoons discharge to the Mississippi River at the NPDES permitted outfall.

2.3.4 <u>On-Site Storage-Treatment-Disposal Units</u>

The On-Site Storage-Treatment-Disposal Units utilized by Shell Oil Company at Wood River consist of eight sites numbered 1 through 8. All eight numbered sites are clearly identified by large signs showing site number and intended use. There are also surface-water bodies handling runoff from the refinery grounds. These units are identified, together with other surface features, on Figure 3, summarized on Table 2. Table 2 includes basic information provided by Shell Oil Company along with our summation of likely regulatory actions and related current and/or future plans for the waste management units. The following subsections provide a brief description of the nature of each of these waste management units.

2.3.4.1 Site 1 and 2 - Neutralization Pond

The Neutralization Pond is an undiked earth basin contained by higher ground on the west, and contained by a dike approximately 20 feet high on the east. The pond is about 30 acres in size with scattered pools of standing liquid and was previously used to dispose of fly ash. Of an estimated average depth of 15 feet, approximately 12 feet are fly ash with the remainder being lime sludge from water softening.

Currently, Site 1, on the north end of the pond, is used as a disposal site for caustic wastes. These include captured caustic drips, barge unloading casutic waste and spent phenolic caustic from the caustic scrubbing of cracked gasoline. Site 2 on the south end of the pond is used to dispose of waste acids, primarily sulfuric acid captured from barge loading and unloading, drips, and fractional protions of spent alkylation acid. The caustic and acidic waste streams are contained in the impoundment with some of each stream mixing and neutralizing before overflowing to Site 10. There probably is little neutralization of caustic wastes, as there are no structures to assure mixing of the two streams.

Future plans anticipate closure of this facility and disposal of the caustic and acidic waste streams into the process sewer.

Supposedly this unit is extremely old, dating back to the early years of the refinery operation. Little is known regarding its construction, and the only information provided was the drilling and engineering data that is presented in the report "Dike and Sludge Pond Study, Shell Oil Company, Wood River, Illinois" prepared by Woodward-Clyde and Associates, February 11, 1970. Information in this report is based on only one boring but it does indicate that the depth of sludge was on the order of 21 feet below the pond surface elevation of approximately 450 feet Mean Sea Level (MSL). The boring penetrated 4 feet of clay beneath the impoundment bottom. Other borings performed along the diked eastern periphery did not encounter the clay material. It is unknown whether the bottom of this impoundment is the original ground, or is the flat surface of an excavation into the natural soil. The original dike was constructed with a cohesive material reported as "filter clay."

2.3.4.2 Site 3 - Solid Waste Landfill

This site has been used for disposal of solid, non-hazardous wastes including dirt, rock, sand, bricks, lime, sulfur, soda ash and spent FCC catalyst. An earth cover is applied periodically.

2.3.4.3 Site 4 - Dumpster Staging Area

Site 4 is not a disposal site but is an area where trash bins are stored until they are filled and hauled off-site. Materials disposed of by this means include non-hazardous trash (paper, wood, etc.) as well as oily rags. The IEPA has classified the oily rags as a special waste, thus future plans call for segregation at source of these and other special wastes. Segregated special wastes will be disposed of off-site under the IEPA manifest system.

2.3.4.4. Site 5 - Oily Sludge Lagoon

This unit consists of three contiguous surface impoundments where oily tank bottoms have primarily been stored/disposed. Also contained in these lagoons are oily sewer cleaning sludge. There is little free water remaining, leaving an oily-waxy residue. Oil and wax are being recovered by melting with immersion steam heated coils and pumping the melted liquid to a tank truck. Of the 3 ponds, only 2 are still being actively used. The southeast pond will be closed after the recoverable materials have been removed and fresh soil tilled into the contaminated basin soil. No information is available regarding the development of these lagoons and they are presumed not to be engineered facilities.

2.3.4.5 Site 6 - Contaminated Solids Landfill

The Contaminated Solids Landfill Unit is actually a number of solid waste piles where no cover is applied. The main input to this area is hydrocarbon contaminated dirt, rock, sand, and catalyst. Leaded tank bottoms, iron pyrites from equipment cleanup, cooling tower sludge, alumina adsorbent from reformer and spent steam purged BEU diatomaceous earth have also been disposed of here. The hydrocarbon contaminated wastes may be classified as special wastes by the IEPA.

Within the general area of the waste piles is a small surface impoundment, Site 6a. This site, though no longer active, was previously used to dispose of crude tank bottoms.

2.3.4.6 Site 7 - Waste Piles

This area receives a small amount of concrete and rubble disposed as waste piles. The materials are not hazardous and no facility problems are foreseen, although no site-related information is available.

2.3.4.7 Site 8 - Asphalt Waste Impoundment

This unit receives waste and spilled asphalt. Waste asphalt is tilled into the soil and periodically covered with fresh soil. No site information is available.

2.3.4.8 Site 9 - Crude Tank Bottoms Pond (Southwest Property)

These surface impoundments served as storage-treatment-disposal units for oily crude tank washings. The oily bottoms are currently being recovered through the refinery waste oil recovery system. Operations are in progress to remove the residually saturated soils to on-site disposal facilities after which ponds will no longer be used.

2.3.4.9 Site 10 - Solid Waste Basin

This unit is currently used for final disposal of API Separator oily lime sludge, DAF float, and oily centrifuge bottoms. Most materials disposed here are listed as RCRA hazardous wastes. The impoundment covers about 13 acres and is approximately 10 feet deep. This is an above ground impoundment, constructed by placing dikes around the perimeter of the pond. The water level is presently maintained at 4 feet below the top of the dike. Recommendations for dike construction were presented in the report "Dike and Sludge Pond Study, Shell Oil Company, Wood River, Illinois" (Woodward-Clyde & Associates, February 11, 1970). The proposed dike fill materials discussed in the report were sand and silty sands. No construction information was available for review. However, though the present location is immediately north of that described in the report, borings performed indicate that the site is underlain by sands and silty sands. Overflow from this basin is directed to Smith Lake through a pipe with an upper baffle which prevents hydrocarbons from being discharged.

2.3.4.10 North Ponds

The North Ponds consist of two excavated impoundments which are shown on Figure 3. These impoundments receive rinse water from the cleaning of vacuum trucks.

Settled sludge has not been removed from the impoundments, however, the liquid phase drains through open ditches to the Storm Water Basin.

No information specifically regarding development of this site is available, but it is not thought to be an engineered facility.

2.3.4.11 Storm Water Retention Basin and Inlet Ditch System

The Storm Water Retention Basin is located in the northeastern portion of the refinery and is shown on Figure 3. This basin is actually a topographic low bounded by road embankments on the north and east. Storm water enters by way of open ditches from the northeastern portion of the refinery area. Water exits the basin through a below-surface discharge, in order that oil separation can occur before release into the Smith Lake directed drainage ditch. Floating oil is periodically skimmed from the pond surface for recovery, and oily dirt is removed from the bottom. No site information is available and it is not presumed to be an engineered facility.

The Inlet Ditch System consists of a system of open ditches located throughout the northeastern portion of the refinery. These ditches handle storm water runoff and overflow from the North Ponds which are discussed in Section 2.3.4.10. No detailed information is available on the construction of these ditches, however, they are presumed to have been excavated in natural materials and designed only for grade without consideration of infiltration.

2.3.4.12 Smith Lake

Smith Lake is a natural topographic low and is shown on Figure 3. The area has been dissected by a road fill but remains connected with the culvert. This lowland receives water from the Solid Waste Basin and the Storm Water Basin, as well as drainage from property to the north of the developed refinery.

2.3.4.13 Old Tannery Site

The Tannery Site is approximately 25 acres of Shell Oil property, and is shown on Figure 3. Previously the tannery was operated by International Shoe. Since being acquired by Shell Oil, the buildings have been demolished. Buried hides have reportedly been encountered during trenching operations on this site, but no information is available concerning the waste management practices used at the tannery facility while it was in operation.

3.0 SITE CONDITIONS

3.1 GEOLOGY AND SOILS

The Shell Oil Refinery Site at Wood River is located on the broad Mississippi River floodplain locally known as the American Bottoms. This floodplain is bounded by the Mississippi River on the west and the 60 foot high Kendall Hill on the east (Figure 4). The bluffs consist of Peoria loess and Roxana silt overlying Paleozoic shales and limestones. Most of the main property at the Shell Refinery, and the north property west of the present disposal facilities, are underlain by glacial outwash deposits of the Mackinaw Member of the Henry Formation (hm - Figure 4). These deposits extend from the surface to bedrock. The rest of the Shell site is underlain by variable thicknesses of Cahokia alluvium (C - Figure 4) which in turn is generally underlain by Mackinaw outwash overlying bedrock.

3.1.1 Glacial Outwash Deposits

Most of the Shell site, occurring at elevations above approximately 435 to 440 feet MSL, is underlain by the Mackinaw Member of the Henry Formation (Figure 4). This unit consists of well sorted, well bedded sand and gravel outwash that was deposited in the Mississippi Valley by melting water from the Wisconsinan glaciers. Deposits at the site are remnants of these valley-train deposits, and are present both as terraces and beneath the valley alluvium (Lineback and others, 1979; Willman and Frye, 1970). A preliminary examination of available boring logs and preliminary Soil Conservation Service maps indicate that portions of the north property are underlain by fine-grained material at the surface. This material is subsequently underlain by apparently well sorted (clean) fine, medium and coarse sands. In general, texture appears to get coarser with depth.

The uppermost strata in the north property, north of the tank farm, appears to vary in composition from clay to silty or clayey fine sand. According to the Soil Conservation Service the upper 5 feet of soil in this area has moderate to very low permeability.

In portions of the north property, the Mackinaw Member may reach a thickness of approximately 160 feet over bedrock. These coarser outwash deposits are relatively permeable and are utilized by water supply wells in the Wood River-Roxana-Hartford area.

3.1.2 Cahokia Alluvium

Portions of the site approximately below elevations of 435 to 440 feet MSL are underlain by the Cahokia alluvium (Figure 4). This stream or river deposit is dominantly silty because much of it has been derived from the erosion of loess and till. Lenses of sand and gravel generally also have a high silt content (Lineback and others, 1979; Willman and Frye, 1970). A preliminary examination of available boring logs from widely spaced locations indicated that alluvium on the Shell property consists, in general, of a clay layer (3 to 16 feet thick) and underlying fine sands or fine to medium sands. Western portions of the west and southwest properties appear to be underlain by organic silty clay topsoil (0 to 3 feet thick) underlain by interbedded silts and clays. The relative amounts and thicknesses of silt and clay vary both horizontally and vertically across the property. Most of the alluvium appears to consist of sediment that was deposited during intervals of flooding, and portions of the site may also contain coarser tributary stream deposits. In general, the Cahokia alluvium is poorly sorted and less permeable than the underlying outwash deposits. Water wells 1, 2 and 5 at the neighboring Clark Refinery were drilled to bedrock at depths of 106, 114 and 112 feet, respectively. Preliminary inspections of logs from these wells and of a log from a well in the southwest portion of the Clark site indicate that in the western portions of the west and southwest properties approximately 55 to 75 feet of alluvium overlies 42 to 52 feet of glacial outwash. The alluvium/outwash contact at potential Site 2 (see Section 4.2.3) may be confirmed during the Phase II field investigation. The underlying bedrock consists of Pennsylvanian limestone on the east and Mississippian limestone on the west (Bergstrom and Walker, 1956, Figure 4).

3.1.3 Bedrock - Structural Geology and Seismology

Rock does not crop out at this site, however, the bedrock structure can be approximated from outcrops and subsurface data from the surrounding area. The site is located near the eastern end of the Lincoln Fold. This anticlinal structure trends northwest-southeast in northeastern Missouri and approximately east-southeast in Calhoun, Jersey and Madison Counties, Illinois. Several smaller structural features are superimposed on the gently northward dipping flank. In Illinois, the southern flank of the Lincoln Fold forms a steeply inclined, monoclinal flexure known as the Cap au Gres Faulted Flexure. This structure appears to terminate between Grafton and Alton, Illinois, approximately 5 miles northwest of the site. The site is located on the gently southward dipping northern flank of the Troy-Brussels Syncline, north of the north-northwest trending Dupo-Waterloo Anticline (Treworgy, 1979).

The proposed siting criteria in the regulations of RCRA state that a hazardous waste disposal facility cannot be sited in an active fault zone. At the present time there is no evidence for movement along the Cap au Gres Faulted Flexure during the Pleistocene Epoch (Treworgy, 1979). Based upon seismograph records from the St. Louis area the Cap au Gres Faulted Flexure is located in an area of "infrequent earthquakes", and according to published data, several earthquake epicenters have been located in the site area but no active faults have been identified at the site.

3.2 GROUND-WATER HYDROLOGY

3.2.1 General

Ground water in the Hartford-Roxana-Wood River area appears to occur, primarily, under water table conditions (William Shepherd, personal communication) however, semi-confined conditions may occur locally where the fine grained alluvial silts and clays of the Cahokia alluvium, overlie coarse grained alluvium and glacial outwash deposits.

3.2.2 Ground-water Movement

Ground water in the site area is recharged by direct infiltration of precipitation, by inflow of subsurface flow from the bluffs in the Kendall Hill area and from the areas southeast of the plant site, and by lateral infiltration from the Mississippi River. Under natural conditions, it would appear that the ground water in the American Bottoms would flow from the south-southeast to north-northwest, toward the Mississippi River. However, pumping by several wells on-site has lowered the water table and altered its shape into a cone of depression.

The shape and slope of the water table and the general direction of ground-water movement in the glacial outwash and alluvial deposits which underlie the area of the refinery, are shown by the contours on Figure 5. The contours are lines of equal elevation of the water table. The ground water flows perpendicularly across the lines and toward areas where the elevation of the water table is lower. The map shows that the water table is not level or uniform, but is an irregular sloping surface. The irregularities in slope and in direction of slope are caused by differences in saturated thickness, permeability and rate of recharge of the water-bearing deposits, and by withdrawal of water from wells.

The water table map (Figure 5), and a previous water table map (Shepherd, 1974), also shows that the general movement of ground water in the area is modified by the withdrawal of water due to pumping at the refinery, which has created a composite cone of depression in the water table underlying the tank farm.

The tightly spaced water table contours along the eastern edge of the north property suggest possibly that the soil transmissivity (permeability multiplied by the saturated thickness) is relatively low in comparison to the more western areas where the contours are more widely spaced.

3.2.3 Permeability

The permeabilities of the soils underlying the north property are not presently known. The common range of permeability of the type of materials underlying the site, are given below.

SOIL TYPES	PERMEABILITY RANGE[a] (CM/SEC)
Clay-Silt Mixtures	10^{-10} to 10^{-4}
Clay	10^{-10} to 10^{-7}
Silt, Loess	10^{-7} to 10^{-3}
Silty Sand	10^{-5} to 10^{-1}
Clean Sand	10^{-4} to 1
Gravel	10^{-1} to 10^{2}

[a]Freeze, R.A., and Cherry, J.A., 1979, Ground Water, Prentice-Hall, Inc., New Jersey.

3.2.4 Ground-water Quality

The scope of work of the Phase I program did not include an investigation of ground-water quality.

3.3 SITE TOPOGRAPHY AND SURFACE-WATER HYDROLOGY

The following discussion of site topography is based upon an examination of the U.S. Geological Survey (USGS) Wood River 7 1/2' quadrangle and on 1:6,000 scale aerial photographs. Most of the Shell north property ranges in elevation from approximately 443+ to 445 feet MSL. The most level area is a topographic high underlain by the Mackinaw Member of the Henry

Formation located north of the tank farm and east of the Roxana High School. Elevations on the northeast and east portions of the north property range from 430+ to 445 feet. Smith Lake and currently used disposal sites are located in and adjacent to this topographic low area.

The main property is underlain by alluvium (topographic lows) and outwash (topographic highs). Elevations vary from 435+ to 440 feet. Most of the main property is on a level high area at elevations of 440+ feet.

Portions of the site are located within flood hazard zones designated by the Nation Flood Insurance Program Flood Insurance Rate map (FIRM) for the city of Wood River. Both 100 and 500 year flood zones are shown on Figure 6. Zones shown on the FIRM for Wood River have been projected to areas off that document by using aerial photographs and the 7 1/2' Wood River topographic quadrangle. The extent and elevations of these flood hazard areas may be reduced by consruction of flood control structures in the city of Wood River.

Most of Shell's property lies within an area of minimal flooding. Based upon available data, the northeastern and eastern portions of Shell's north property lie within the 100 year flood boundary. Some of this area may also lie within a 500 year flood zone. If levees are built on the Missouri side of the Mississippi River, flood levels in Illinois may be affected. The possibility of future flood control structures in Missouri implies that higher elevations of flood hazard zones in or adjacent to the site are possible.

3.4 WETLANDS AND CRITICAL HABITAT

3.4.1 Endangered or Threatened Species

There are no recorded occurrences of state or federally designated endangered or threatened species near the city of Wood River (Becker, 1980). The nearest locations on record are approximately 8 miles south. There are also no critical habitats for endangered or threatened species in the vicinity of the city of Wood River. Therefore, it is expected that construction or operation of the waste disposal facility would not jeopardize the continued existence of any endangered or threatened species.

3.4.2 Wetlands

There are several wetlands within Shell Oil properties near Wood River. Some of the areas are natural while others appear to have been man-made or substantially modified by man. One area is located on approximately 160 acres in the southern one-half of Section 26, T5N, R9W (Figure 6). Most of this area is agricultural land and does not appear to support typical wetland vegetation. There are no wetlands indicated on the 7 1/2' USGS map for this parcel, but the USGS map does indicate wetlands occurring immediately to the east of this parcel (Figure 6). Site reconnaissance would appear to be necessary to further define the conditions.

3.5 CLIMATOLOGY

The site region has a continental climate, with warm summers, cold winters, and frequent and rapid variations in temperature, humidity, cloudiness, and wind direction. Storm systems affect the site region most frequently during the winter and spring seasons. Much of the precipitation during the summer months results from shower and thunderstorm activity associated with frontal passages or unstable air masses.

Local climatological conditions in the site region can be described using surface observations from the First Order National Weather Service (NWS) station at Lambert Field, near St. Louis, Missouri (U.S. Department of Commerce, 1974). This station is the closest First Order NWS station to the proposed site, and its climatological data are considered representative of conditions in the site region due to its proximity to the site and the availability of meteorological data records from many years.

Based on observations made during the period of 1931 to 1960, the annual average temperature is estimated as 55.3°F; with a mean daily maximum temperature of 65.6°F and a mean daily minimum of 45.0°F.

For the same 30 year period of record, the annual average precipitation is 35.31 inches. The maximum monthly average precipitation is 4.29 inches from June. The months December through February are the driest, each month averaging only about 2 inches of precipitation. Snowfall has been recorded as early as October and as late as May. However, the long-term average snowfall equals or exceeds 0.1 inch during the season from November through April. A monthly maximum of 22.3 inches of snowfall was recorded during March, 1960; a 24-hour maximum snowfall of 11.2 inches was observed in January, 1958. The annual average relative humidity is approximately 67 percent.

Southerly winds are most prevalent during the months of May through November. West-northwest through northwest winds prevail only from December through April, causing the annual prevailing wind direction to be from the south. The annual average wind speed, regardless of wind direction, is about 9.5 miles per hour.

00216-222-07

4.0 PRELIMINARY SITE SELECTION FOR THE NEW DISPOSAL FACILITY

Preliminary geological, hydrological, and ecological studies were performed in order to select a site on the Shell Oil Refinery property for the development of an ultimate surface storage impoundment facility which will meet applicable state and federal requirements as promulgated under RCRA. This phase of preliminary selection was limited to studies of 7 1/2' and 15' USGS topographic quadrangle maps, preliminary Soil Conservation Service maps, available Flood Insurance Rate maps, data directly supplied by Shell Oil Company and site visits by Dames & Moore Principal Investigators.

4.1 CRITERIA OF SITE SELECTION

4.1.1 Criteria

A number of criteria were used to determine the suitability of potential sites. These criteria included geology and soil type, ground-water hydrology, proximity to populated areas, topography, and distance from the plant. Other considerations which guided the selection process were the rules and regulations of RCRA as proposed on December 18, 1979 (Section 3004, Subsection 250.43 and 250.45). These are outlined below:

I. General Facility Standards*

A. Sites should not be located in these areas:

1. Active fault zone;
2. Regulatory floodway (the 100 year floodplain as defined by the FIA);
3. Coastal high hazard area (FIA);
4. 500 year floodplain;
5. Wetlands; and
6. Recharge zone of a sole source aquifer.

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*Federal Register, vol. 43, no. 243, December 18, 1978.

B. Buffer zone of at least 200 feet should be maintained between active zone and property boundary.

C. Ground-water monitoring and leachate monitoring systems are required.

II. <u>ULTIMATE SURFACE IMPOUNDMENT</u>*

1. It will not come into contact with navigable water;
2. The bottom of the soil barrier is at least 5 feet above the historical high ground-water table;
3. It is at least 500 feet from the nearest public or private water supply;
4. The soil barrier meets the following requirements:
   a. Permeability of 1×10^{-7} cm/sec (0.1 foot/year) or less;
   b. Unified Soil Classification of CL, CH, SC, or OH;
   c. At least 30 percent passes the No. 200 sieve;
   d. Liquid limit of at least 30;
   e. Plastic limit of at least 15;
   f. pH of at least 7;
   g. Permeability not adversely affected by wastes.
5. The soil underlying the soil barrier has permeability less than 1×10^{-4} cm/sec (100 feet/year).

These guidelines are preliminary and may possibly change with the addition of new Phase 2 RCRA regulations. However, three generic terminal surface storage impoundment designs that incorporate the latter requirements are illustrated on Figures 7, 8, and 9.

Climatology was not a factor in site selection as weather does not vary across the Shell property; however, it does affect the design and operation of a facility.

A major consideration in evaluating existing facilities or in siting the new disposal facility is the potential for contamination of ground water. The EPA has long stressed the protection of air and surface matter, however, the recent RCRA regulations also seek to protect ground-water resources. As a result, the permeability of the sub-surface soils and the elevation and direction of ground-water movement are key parameters that must be defined

*Federal Register, vol. 43, no. 243, December 18, 1978.

in the evaluation or selection of a facility site. Below is given a brief discussion of the way each of the prinicpal parameters was used in selecting sites.

4.1.2 Geology and Soil Type

On the basis of reviews presented in Section 3.1.3, the site region is geologically suitable for a hazardous waste disposal facility. The criteria for selection are that no active fault zone or other relevant geological features are associated with the site or found in the general vicinity.

Sections 3.1.1 and 3.1.2 also identify two major soil deposits on the Shell property: glacial outwash deposits and Cahokia alluvium. The approximate distribution of these deposits is shown on Figure 4. Because finer grained soils are considered preferable to coarser grained soils, sites underlain by silt or clay soils are preferred to those underlain by sand or gravel soils. Finer grained soils are considered to be superior for two reasons. First, their lower permeabilities would lessen the chance that leachates from hazardous wastes could be transmitted from the disposal site through the pond bottom to nearby surface waters or to the ground waters. Secondly, clayey soils could provide a suitable local source for fill material to be used in constructing dikes and liners in the disposal pond.

4.1.3 Ground-water Hydrology

The permeability of the soils, as mentioned in the previous paragraph, is an important siting consideration. The coarse grained nature of some of the surficial deposits at the Shell Oil Refinery may make potential disposal sites either geologically or hydrogeologically unsuitable for the development of an unlined ultimate waste disposal facility.

The elevation and direction of movement of ground water are other key parameters. As explained in the section on ground-water hydrology, due to the lower transmissivity and lower rate of ground-water movement, the area along the eastern margin of the north property might be a possible location for a new disposal site. The water table in the eastern portion of the north property is nearer to the ground surface than in the west because the water table is naturally higher in the low land area (Figures 5 and 6). The RCRA regulations propose that 5 feet of unsaturated material separate the base of any impoundment liner from the historic high water table.

The general movement of ground water at the Shell Oil Refinery has been modified by the cooling water source (process makeup) well field. Ground water moves towards the center of the cone of depression (Figure 5). As a result, the area north of the tank farm might also be considered a likely location for a new landfill. Based on the water table map, the area is within the effective radius of the core of depression centered on the tank farm. Due to water table drawdowns and the higher surface elevation, the water table is approximately 40 to 45 feet below the ground surface, allowing for a greater depth of separation between ground water and the disposal facility than elsewhere on the north property.

4.1.4 Proximity to Populated Areas

Population distribution was considered during Phase I. Populated areas and properties off-site were avoided in site selection.

4.1.5 Topography

Topography was examined with a view toward identifying those areas where a relatively large, flat expanse or a slight depression exist. Areas with these topographic features were selected because they would require a minimum amount of land surface modification and would allow construction of shorter or lower dikes for containment of the waters in the disposal pond. The number of suitable areas was extremely limited both because of prior established usage and drainage conditions which made most of the flatter low-lying areas unusable. Those areas deemed most suitable for the intended purpose were the better drained upland areas out of flood hazard zones.

4.1.6 Flood Hazard Areas

In the proposed RCRA regulations, hazardous waste management facilities used in treatment, storage, and disposal of these wastes cannot be located in a "regulatory floodway." If a facility is located in the 500 year floodplain, it shall be designated and maintained so that it will not be inundated by the 500 year flood. Therefore, a facility in flood hazard areas would be more expensive to design, construct and maintain. The flooding potentials on the Shell property are shown on Figure 6.

4.1.7 Wetlands and Critical Habitats

Under the RCRA regulations cited previously, hazardous waste facilities cannot be located in a wetland or in a location likely to jeopardize the continued existence of endangered or threatened species.

Wetlands are present on the Shell property and were considered in the siting process. However, since there are no recorded occurrences of state or federally designated endangered or threatened species near the Shell Refinery this was not a factor in site selection.

4.1.8 Distance from the Plant

The suitability of a proposed disposal site was considered to vary inversely with its distance from the generating facility. The closer the disposal site was to the plant, the more suitable it was from the standpoint of the costs and environmental effects of tranporting hazardous wastes to the disposal site. For purposes of evaluating this factor, distances were scaled from the west property, DAF 1.

4.2 SITE RATING

4.2.1 Site Rating Scheme

The candidate areas are labeled as Sites 1 through 4 (Figure 1), and were rated as potential ultimate waste disposal sites according to the following scheme.

Each parameter was rated on a scale ranging from +2 to -2. A positive rating for a parameter indicates that the site is well suited for the intended use, while a negative score indicates that some problems exist which may or may not prove to be correctable. A rating of zero for any parameter indicates that the particular site is neither uniquely suited for the intended purpose nor are there any special negative aspects which should be taken into consideration. The rating system is entirely subjective and is intended only to give a general idea of the relative suitability of one site compared to others. Ratings of the four potential sites are presented in Table 3.

4.2.2 Potential Site 1

This site is a relatively large, almost flat area located approximately 4,000 feet from the Master Oil Separator. The land surface appears to slope gently toward the center of Site 1. Except for the upper 5 feet, the outwash deposits which underlie Site 1 appear, on the basis of our interpretation of driller's boring logs and driller's performance tests, to be relatively permeable. The use of a clay liner would make this a feasible site if the soil underlying the liner has a permeability less than 1 x 10^{-4} cm/sec. The water table is currently approximately 40 to 45 feet below ground surface.

Though Site 1 is away from flood hazard areas and wetlands a possible drawback to its selection is its proximity to the town of Roxana (Figure 1). The disposal facility must be located a minimum of 200 feet from the property line. Freedom to move the facility westward is limited because the area slopes toward wetlands and the Smith Lake drainage area (Figure 1). The distance between the town and disposal facility should be maximized. The site is feasible only as long as a 5 foot separation can be maintained between the bottom of the liner and the water table, and the material underlying the liner has a permeability less than 1 x 10^{-4} cm/sec.

4.2.3 Potential Site 2

This site is located approximately 8,500 feet from the Master Oil Separator, and may possibly be limited by the flood hazard and/or wetlands boundary. The extent and elevation of the flood hazard zone may be reduced by construction of flood control structures in the city of Wood River. These boundary conditions would have to be determined during Phase II. The natural alluvial clays and silts which likely underlie Site 2 should have a relatively low permeability. Site 2 appears to be in an area of lower transmissivity and a lower rate of ground-water movement. However, the water table is relatively close to the land surface and the facility may have to be raised to a higher elevation with a thicker clay liner to maintain adequate ground-water separation.

Site 2 is located approximately 1,000 feet northwest of the town of Wanda. Ground water, however, moves west from Site 2 and any leachate originating on Site 2 would tend to flow in a direction away from Wanda. The expansion of Site 2 to include areas underlain by loess deposits should be investigated during Phase II.

4.2.4 <u>Potential Site 3</u>

Site 3 is located approximately 5,000 feet from the Master Oil Separator and is underlain by Cahokia alluvium. The thickness and areal continuity of near-surface clays and silty clays would have to be confirmed by a field investigation. Ground-water levels within the finer grained alluvium and the direction of ground-water movement might necessitate the use of an additional clay liner. Site 3 is relatively far from populated areas but may be too small to contain a sufficient interface between the disposal facility and the wetlands and flood hazard area (Figure 1). The proximity of this site to the Grassy Lake wetlands and flood hazard areas eliminates this site from further consideration.

4.2.5 Potential Site 4

This site is located approximately 5,000 feet from the Master Oil Separator and is underlain by Cahokia alluvium. The thickness and areal continuity of near surface clays and silty clays would have to be determined by a field investigation. Ground-water levels and the direction of ground-water movement might necessitate the use of an additional clay liner. The previous utilization of Site 4 would probably make its use as a disposal area too costly thus eliminating it from further consideration.

4.2.6 Conclusions

The advantages and disadvantages of each site have been discussed as thoroughly as is presently possible. The nearest wetlands and flood hazard boundary will be confirmed prior to drilling at potential Site 2. Potential Site 3 is considered to be less desirable due to the proximity of wetlands and a flood hazard zone, however, this suspicion will be confirmed during Phase II of the study. Prior use of Site 4 will probably eliminate it also from future consideration. In conclusion, it has been found that potential Sites 1 and 2 are most obviously worthy of further site selection consideration.

5.0 RECOMMENDATIONS FOR PHASE II PROGRAMS

5.1 OBJECTIVES AND CONCEPTUAL APPROACH

Existing data related to site conditions and waste management facilities were reviewed in the Phase I studies. Generally, the results of this review indicated that no major site-related factors existed that would prevent the construction and operation of an ultimate, hazardous waste surface impoundment facility. There are, however, specific geologic and hydrologic conditions that are not known at the present. For instance, both the availability of a sufficient natural clay barrier and ground-water conditions at the potential site locations are yet uncertain. The review indicated that for most of the existing waste management facilities there is a lack of sufficient data for evaluation regarding regulatory compliance and necessary upgrading.

The major objective of the Phase II studies will be to obtain site specific (soils and hydrogeologic) data at the proposed new facility sites. These data will be utilized to develop conceptual designs, and compare costs for various alternatives at potential sites. The Phase II study will also enable the development of documents for permit application. A generic plan for closure of the existing waste management units will also be developed.

Furthermore, during the Phase II investigation, Dames & Moore will be available for consultation with the Shell Oil staff: assessing the need for further waste characterizations; discussing alternatives and strategy for waste segregation, recovery, reuse, treatment, storage and disposal; and assisting, if requested, in the preparation of documents for permit applications.

The following sections of this chapter will describe in more detail the investigative programs being proposed.

5.2 INITIAL INVESTIGATION FOR NEW SITES

The initial investigation for the proposed new facility sites will consist of the following tasks.

1. Drilling of borings and installation of piezometers at the two proposed locations for the ultimate waste management facility;

2. Sampling and testing of soil samples at the two sites; and

3. Locating possible borrow sources of clay liner materials.

5.2.1 Drilling of Borings and Installation of Piezometers

It is proposed that a total of 14 (8 at Site 1 and 6 at Site 2) borings be made in the initial phase of the site investigation in order to gather information to define the general soil stratigraphy and areal boundary of soil types in the areas of the proposed new waste management facilities. Based on the existing data, we anticipate that the borings will have to be on the order of 70 feet deep to provide the level of information necessary to design the new facility, and to provide sufficient information to the regulatory agencies to demonstrate the adequacy of the design developed. It is proposed that a total of seven piezometers will be installed in the borings. These piezometers will become part of a larger, more comprehensive monitoring network that would surround the new ultimate waste management unit, as required by RCRA regulations.

The piezometers will be installed in 4-inch diameter boreholes and constructed using 2-inch diameter PVC (plastic) pipe. The piezometer screen will be in the upper most 10 feet of the water table. The annulus between the borehole and the screen will be filled with clean pea gravel filter, the gravel pack extending to about 1 to 2 feet above the screen to compensate for any settling during development. Approximately 1 to 2 feet of sand will be placed over the gravel pack and the piezometer screen sealed with a 2 foot layer of bentonite. The piezometer will then be grouted to the surface to insure a more complete seal of the borehole, and each piezometer will be protected against damage by a 4-inch steel pipe driven into the ground and grouted in-place.

Safety procedures will be required during investigations of the proposed facility and existing units. Field investigations, sample shipment, and laboratory analyses will be conducted in a manner that will minimize exposure by field and/or laboratory personnel, as well as the general public, to potentially hazardous wastes. Details of these safety procedures and related costs will be discussed with Shell Oil Company personnel at a later date.

5.2.2 Sampling and Testing of Soil Samples

The purpose of this task is to establish the physical characteristics of the soils located above and below the ground-water table, giving particular emphasis to defining the physical properties of the clay units underlying the two proposed sites. Samples of the soils will be obtained from each boring during drilling, utilizing a Dames & Moore type U sampler, a shelby tube sampler and a standard split spoon sampler. Special emphasis will be placed on samples from the upper 15 feet of each boring and any clay units encountered.

All soil samples will be taken to the soils laboratory for visual examination and physical testing. The following laboratory tests may be performed on selected samples from each boring:

1. Grain-size analysis;
2. Atterberg limits;
3. Vertical permeability;
4. Density; and
5. Moisture content.

At the conclusion of our program, the soil samples will be returned to Shell for chemical tests and for final disposal.

5.2.3 <u>In-Situ Permeability Tests</u>

The 7 piezometers that are installed and developed at the 2 proposed sites will undergo short (1 hour to 2 hour) in-situ permeability tests. The resulting data from these tests will provide additional information for describing the hydrogeology of the two areas and for determining the velocity of ground-water flow.

5.2.4 <u>Investigation of Borrow Sources of Clay Liner Materials</u>

It is possible that the new ultimate waste disposal facility will have to be equipped with a impermeable liner in order to be permitted under RCRA. In the Phase II program, therefore, processors and construction contractors who would be familiar with possible sources and the quality of locally available clay will be contracted. In addition, possible borrow sites of clay liner materials will be identified through a review of available soil and aerial maps of the Roxana-Hartford-Wood River area.

Each potential source of clay materials will be visited by a qualified Dames & Moore soils engineer who will examine, classify, and obtain representative samples of the clay from stock piles at existing borrow areas. Samples of the clay materials will be subjected to the following tests:

1. Grain-size analysis;
2. Atterberg limits;
3. Compaction; and
4. Permeability.

The results of the laboratory tests will be compared with RCRA requirements to assess the suitability of the clay as liner material. After the clay source has been identified, samples of the clay will be obtained and tested for compatability with the waste materials. This testing will be completed during Phase III of the program. In the event that the locally available clay is found to be unsuitable as a liner, methods for upgrading the clay by addition of bentonite or other additives, will be investigated. Other types of liner materials such as asphalt, and/or synthetic liners will be evaluated as alternatives to clay.

5.3 DEVELOPMENT OF A GENERIC CLOSURE AND POST-CLOSURE PLAN

The primary objective of this task will be to develop a generic closure and post-closure plan to meet applicable state and federal requirements as promulgated under RCRA of 1976. The scope of our task will consist of the following:

A. Develop a General Closure Plan to provide the following (265.112):

   1. Description of how and when the facility will be partially closed and ultimately closed (265.112 & 265.113);

   2. Estimate of maximum extent of operation which will be unclosed during the life of the facility;

   3. Estimate of the maximum inventory of wastes at any given time;

00216-222-07

4. Description of steps needed to decontaminate facility equipment during closure.

5. Schedule for final closure:

    a) Anticipated date when wastes will no longer be received,
    b) Anticipated date of completion of final closure, and
    c) Intervening milestone dates.

B. Develop a Specific Closure Plan to include the following:

1. Description of how waste and residues will be removed from tanks;

2. Determination of surface impoundment material removal:

    a) Determine if all impoundment materials will be removed. If so, describe how they will be removed.
    b) If materials are not removed, prepare closure plan following landfill requirements; describe how liquids and residues will be handled to support final cover.

3. Address the following factors related to land treatment:

    a) Control of migration of hazardous waste and constituents in ground water;
    b) Control of release of contaminated runoff into surface water;
    c) Control of release of airborne contaminants; and
    d) Compliance with food chain crop requirements.

4. Address the following factors related to landfill:

    a) Function and design of final cover;
    b) Control of pollutant migration;
    c) Control of surface-water infiltration, including prevention of pooling;
    d) Prevention of erosion; and
    e) Need for leachate collection, removal and treatment system or gas collection and control system.

C. Develop a General Post-Closure Plan:

1. Describe ground-water monitoring activities and frequencies;

2. Describe maintenance activities and frequencies to ensure:

    a) Integrity of cap and final cover of other containment structures; and
    b) Ensure functioning of monitoring equipment.

D. Develop a Specific Post-Closure Plan:

1. Provide a description for factors related to land treatment including:

   a) Maintenance of monitoring system;
   b) Manner and frequency of collection and analysis of samples;
   c) Restriction of access; and
   d) Compliance with food chain crop requirements.

2. Provide a description for factors related to landfill including:

   a) Maintaining function and integrity of final cover;
   b) Maintaining and monitoring leachate system if one exists;
   c) Maintaining and monitoring gas collection and control system, if one exists;
   d) Protecting and maintaining surveyed benchmarks; and
   e) Restricting access.

E. Financial (265.142)

1. Prepare Cost Estimates for Facility Closure and Post-Closure and Develop a System for Revising Estimates.

5.4 PREPARATION OF TOPOGRAPHIC MAP

Dames & Moore will, through its subcontractor and working in conjunction with the Shell Oil Staff, complete topographic maps of the proposed new facility sites.

5.5 ADDITIONAL SITE INVESTIGATION

In the event that there is a favorable outcome from the investigation of the sites for the new disposal facility, but the level of confidence is inadequate to provide a defensible case to regulatory agencies, specific additional studies will be identified. Such studies might include closer spacing of soil borings and placement of additional piezometers within and adjacent to the potential new facility site. This will be done in order to make a more extensive survey of the subsurface soils and ground-water quality so that the most favorable site for the proposed new facility and its design needs can be determined. If required, a detailed field investigation will be performed to evaluate the quality and quantity of the clay liner material at the identified borrow sites.

5.6 OTHER PHASE II TASKS

5.6.1 Assisting in Preparing Permit Application Documents

At Shell Oil's request, Dames & Moore will assist in the preparation of documents for permit applications for both the existing Solid Waste Basin as well as the proposed new waste management facilities. In addition, the Phase 1 regulations promulgated on May 19 as "Interim Status Standards for Hazardous Waste Treatment, Storage, and Disposal Facilities" (40 CFR Part 265) become effective on November 19, 1980. They entail general requirements including: requirements for waste analyses, security inspections, personnel training, preparedness and prevention systems, contingency planning and emergency procedures, the manifest system, record keeping and reporting, ground-water monitoring, closure and post-closure care, and partial financial responsibility for all types of hazardous waste management facilities (HWMF). In addition, standards for specific types of facilities govern such aspects as waste analysis and trial tests, inspections, and general operating requirements. These 10 facility types are as follows:

- Containers
- Tanks
- Surface impoundments
- Waste piles
- Land treatment
- Landfills
- Incinerators
- Thermal treatment
- Chemical, physical, and biological treatment
- Underground injection

The regulations specify a number of requirements that must be prepared by November 19, 1980. These include the following:

265.13	Waste Analysis and Plan
265.14	Security
265.15	Inspection (Inspection Plan)
265.16	Job Description
265.32	Required Equipment (in place)
265.51	Contingency Plan (all facilities)
265.71	Manifest System
265.73	Operating Record
265.110	Closure Plan (all facilities)
265.117	Post-Closure Care (disposal facilities)
265.142	Cost Estimate for Facility Closure (all facilities)
265.144	Cost Estimate for Post-Closure Care (disposal facilities)
265.173	Management of Containers
265.192	Tanks - Overflow Protection for Open Tanks
265.223	Impoundments - Freeboard and Dike Protection
265.251	Piles - Wind Dispersal Protection
265.343	Incinerators - Operating and Maintenance
265.382	Thermal - Open Burning Prohibited
265.400	Chemical/Physical - Operating

In addition, by May 19, 1981, all personnel must have successfully completed a training program.

Other reporting and documentation requirements are also defined by the Phase 1 standards.

The following Interim Standards must be complied with by November 19, 1981.

265.91	Ground-water Monitoring (impoundment, landfill, and treatment)
265.92	Sampling and Analysis
265.93	Preparation, Evaluation, Response
265.253	Piles - Containment (run-on/run-off)
265.272	Land Treatment - Operation (run-on/run-off)
265.302	Landfills - Operating (run-on/run-off, wind dispersal)
265.314	Landfills - Requirements for Liquid Wastes
265.315	Landfills - Requirements for Containers

Dames & Moore will be pleased to assist Shell Oil in any manner needed to complete these requirements.

5.6.2 Consultation Regarding Waste Management Alternatives

Dames & Moore will be available for consulation to Shell Oil with respect to strategy and alternatives for waste management. On the basis of data developed during this investigation, Dames & Moore will suggest alternatives for waste segregation, recovery and reuse; and on-site/off-site treatment, storage and disposal.

6.0 REFERENCES

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TABLE 1

DESCRIPTION OF HAZARDOUS WASTE

HAZARDOUS WASTE NO.	DESCRIPTION	SOURCE	BASIS FOR HAZARDOUS DESIGNATION
A. HAZARDOUS WASTE FROM NON-SPECIFIC SOURCES			
F001	Spent degreasing solvents and sludge	(a) Dispatching (b) Quality Control (c) Maintenance (d) CCU	Chlorinated Hydrocarbon (Toxic)
F003	Spent solvents (DMK) and distillation bottoms	DMK	Ignitability Reactivity Corrosivity
B. HAZARDOUS WASTE FROM SPECIFIC SOURCES			
K048	Dissolved air floatation (DAF) float from Petroleum Refinery Industry (PRI)	Utilities	Chromium Lead (Toxic)
K049	Slop oil emulsion solids from PRI	Utilities	Chromium Lead (Toxic)
K050	Heat exchange bundle cleaning sludge from PRI	(a) Distilling 1 & 2 (b) Gas (c) Alky (d) BEU (e) Precursor (f) RAU/CAU (g) Stabilizers/ Treaters (h) Sulfur Recovery (i) Sulfuric Acid (j) Acetone (k) CCU 1 & 2 (l) Lube F & E D & D (m) Utilities-sewer (n) Mtc-sewer (o) SATS Gas (p) CR-1 (q) Hydrocracker	Chromium (Toxic)

Reference: Reproduced from data supplied by Shell Oil Company.

HAZARDOUS WASTE NO.	DESCRIPTION	SOURCE	BASIS FOR HAZARDOUS DESIGNATION
		(r) CR-2 (s) KHT (t) DHT (u) HDU-1 (v) HDU-2 (w) CR-3 (x) Asphalt	
B. HAZARDOUS WASTE FROM SPECIFIC SOURCES (continued)			
K051	API Separator sludge from PRI	Utilities	Chromium, lead (Toxic)
K052	Tank bottoms (leaded) from PRI	Dispatching	Lead
C. COMMERCIAL CHEMICAL PRODUCT HAZARDOUS WASTE			
P110	Tetraethyl lead	Dispatching (piping and/or equipment containing residue) include products P.L. leaded gasoline filters	Toxic
U013	Asbestos	Refinery	Toxic
U019	Benzene	BEU (a) BEU filter clay (b) Sludge from equipment (c) Contaminated sand Refinery: Benzene Filters	Toxic
U188	Phenol	Phenolic sludge from (a) Extraction Reboilers (b) Phenolic Pits Gloves, apparel contaminated with phenol Sand contaminated with phenol	

TABLE 2

WASTE STORAGE, TREATMENT, AND DISPOSAL UNITS
SHELL OIL COMPANY - WOOD RIVER, ILLINOIS

UNIT	TYPE[a]	DESCRIPTION	INPUTS(AND OUTPUTS)	DISPOSITION
Sites 1 and 2 - Neutralization Pond	S,T,D	Site 1 is on the north end and Site 2 is on the south end of an old fly ash disposal pond. This is an undiked earthen basin of about 32 acres with pools of standing liquid. Of an original 15-foot depth, 12 feet are fly ash, remainder is lime sludge. Currently, Site 1 is used for disposal of "weak" caustic wastes and Site 2 is used for "weak" acidic wastes. It is assumed that some degree of neutralization occurs between the Site 1 and Site 2 acid-base wastes.	Site 1 (weak caustics) a. Barge loading/unloading caustic line drainings; 500 bbl/yr; pH 12 to 13.5; TOC 5 to 10,000 ppm. b. Water draw off from gasoline component tanks; 8,000 bbl/yr; pH 12 to 13.5; contains phenols and possible hydrocarbons. c. Miscellaneous streams from various units; 300 bbl/yr; pH 8 to 14. Site 2 (weak acids) a. Barge loading/unloading acidic line drainings; 600 bbl/yr; 5 to 90 percent H_2SO_4; approximately 5 percent hydrocarbons b. Waste acid from alkylation/precursor units and sulfuric acid plant; 5,000 bbl/yr; greater than 67 percent H_2SO_4 Treatment and residue sludges accumulate on bottom of pond.	1. Liquid effluent overflows to Site 10, Solid Waste Basin; remainder percolates, evaporates; composition unknown. 2. Settled sludges accumulate in pond and have not been removed; quantity and composition unknown. 3. Future plans anticipate closure of this facility and utilization of treatment facilities for the acid - base wastes.
Site 3 - Solid Waste Landfill	D	Solid waste piles - landfill for dry, primarily nonhazardous wastes.	1. Uncontaminated dirt, rock, sand, bricks, lime (CaO); 6,000 T/yr. 2. Elemental sulfur (m.p. 95°C) plugs from molten sulfur storage pits; 20 T/yr. 3. Water damaged bulk soda ash (Na_2CO_3). 4. Spent cat crack catalyst (zeolite, alumina, silica); coke has been burned off; 400 T/yr; bulk of spent equilibrium catalyst is hauled off site for disposal.	1. This is a final disposal area for solid wastes. 2. Runoff and percolation may generate a corrosive $Ca(OH)_2$ solution from disposed lime.

Note: This summary is compiled on the basis of information supplied by Shell Oil Company.

[a]S = Storage, T = Treatment, D = Disposal

WASTE STORAGE, TREATMENT, AND DISPOSAL UNITS
SHELL OIL COMPANY - WOOD RIVER, ILLINOIS

UNIT	TYPE[a]	DESCRIPTION	INPUTS (AND OUTPUTS)	DISPOSITION
Site 4 - Dumpster Staging Area	S	Storage and transfer area for general, primarily nonhazardous trash; trucks dump load of trash into steel dumpster bins for periodic off-site hauling and disposal.	1. Trash - paper, wood, etc. 2. Special wastes including oily trash.	1. Periodic hauling of dumpster bins for contract off-site disposal. 2. Future plans call for separation of special wastes.
Site 5 - Oily Sludge Lagoon	S,T,D	Three contiguous lagoons where primarily oily tank bottoms generated from periodic tank maintenance clean-out have been dumped. Most of the water has percolated/evaporated, leaving waxy, oily residue.	1. Oily, crude and noncrude tank bottoms from tank cleaning; 5,000 T/yr; contains oil, wax, rust, dirt, and water. The water fraction could be toxic due to heavy metals; the hydrocarbons could to be ignitable 2. Oily sewer cleanings; 1,100 bbl/mo; unknown composition. Likely similar to API Separator sludge; thus, likely hazardous due to heavy metal (Cr, Pb) toxicity.	1. Oil-wax is being recovered by steam coil melting and pumping to tank truck. 2. Currently, only two of the three lagoons are being used. 3. Future plans call for disposal of generated wastes in RCRA permitted site; southeast pond will be closed after fresh soil is tilled into surface; soil must be examined to evaluate extent of effects. 4. Leaded wastes are currently disposed of off-site.
Site 6 - Contaminated Solids Landfill	D	Solid waste piles; not covered daily; inputs mainly solids that contacted process streams.	1. Hydrocarbon contaminated dirt, rock, sand, catalyst; 1,300 T/yr. 2. Spent, steam purged benzene extraction unit (BEU) diatomaceous filter; 50 T/yr; leachate analysis has been completed. 3. Spent alumina absorbent from reformer; 25 T/yr; contains HCl; pH 4; 12.5 percent chloride. 4. Cooling tower sludge; 20 T/yr; consists of biological and lime sludge with chromium. 5. Iron pyrites from equipment cleanup; 5 T/yr; probably hazardous due to reactivity.	1. This has been and is being used as a final disposal facility. 2. Hydrocarbon soaked materials are classified as Special Wastes by IPCB. 3. Leaded wastes are currently disposed of off-site.

WASTE STORAGE, TREATMENT, AND DISPOSAL UNITS
SHELL OIL COMPANY - WOOD RIVER, ILLINOIS

UNIT	TYPE[a]	DESCRIPTION	INPUTS (AND OUTPUTS)	DISPOSITION
Site 6a - Crude Bottom Impoundment	D	This is a pit/small lagoon within Site 6, previously used for disposal of crude tank bottoms; no longer an active disposal site.	Crude tank bottoms; unknown quantity or age.	Although not an active disposal site, considerations similar to those of Site 5 (Oily Tank Bottoms Lagoons) should be applicable.
Site 7 - Waste Piles	D	Waste pile.	Concrete and rubble; 30 T/yr.	No presently foreseen problem; capacity unknown.
Site 8 - Asphalt Waste Impoundment	D	Surface impoundment?	Asphalt from spills; 700 T/yr; polynuclear hydrocarbons; low leachability.	No presently foreseen problem; capacity unknown.
Site 9 - Southwest Property Pond	S,T,D	Surface impoundment; used for storage and periodic recovery of crude tank bottoms.	Washings from cleaning crude tank bottoms; 20,000 bbl/yr; 20 percent crude oil, 15 to 20 percent solids, balance water.	Use of this site is being phased out. Alternative methods for crude tank cleaning are being investigated.
Site 10 - Solid Waste Basin	S,T,D	Pond, 10 feet deep, 13.5 acres, with 5 to 6 feet of sludge and liquid. Imput sludges are pumped from treatment units into one end of the pond. Bottom is assumed sealed with lime sludge.	1. Lime sludge from water treatment added to oily water to scavenge oil; collected as API Separator sludge. Hazardous due to EPA classification K051, Cr, Pb toxicity of API Separator sludge. Effect of lime sludge on API Separator is unknown. Quantity of this flow is 30 TPD. 2. West property effluent; character of this stream is unknown, but combined with above stream, 250 gpm; 0.8 percent dry weight solids; 5,000 ppm oil and grease. 3. Oily centrifuge bottoms consisting of slop oil emulsion solids, K049; 60 bbl/day.	This is a final disposal site. Accumulated liquid overflows to Smith Lake inlet via a submerged pipe with a cap baffle to prevent the overflow of floating oil. Some volume reduction probably occurs due to evaporation/percolation of water.

WASTE STORAGE, TREATMENT, AND DISPOSAL UNITS
SHELL OIL COMPANY - WOOD RIVER, ILLINOIS

UNIT	TYPE[a]	DESCRIPTION	INPUTS (AND OUTPUTS)	DISPOSITION
North Property Ponds	S,T,D	Small ponds next to vacuum tank truck clean-out area.	Drainings from vacuum tank truck cleaning; 1,000 bbl/yr; oils, sludges, water; 1 percent hydrocarbons	Liquid phase overflows to Storm Water Basin; sludge has not been removed. New facilities for vacuum truck cleaning will be provided to eliminate these problems
Storm Water Basin	S,T	Pond adjacent to Smith Lake; surface runoff and other flows delivered by open ditch system.	1. North Property Ponds overflow effluent containing primarily floating hydrocarbons. 2. Surface storm water runoff.	Floating hydrocarbon phase is skimmed with vacuum tank trucks; effluent water discharged to Smith Lake.
Smith Lake	S	Surface impoundment; north and south sections separated by road, connected by culvert; no outlet.	Water effluent from Storm Water Basin.	Smith Lake water percolates/ evaporates.
API Separators: Master Box, Box 11, and other oil separator boxes	S,T	Two concrete basins connected by piping.	1. Oily water sewer system feeds Box 11, oily water effluent from Box 11 and other separator boxes feeds Master API Box. 2. Slop oil skim. 3. API Separator sludge (K051).	1. Effluent from Master Box feeds the Aeration Basin. 2. Skimmed slop oil to Recovery Unit (Work Tanks). 3. Sludge to Solid Waste Basin.
Work Tanks	S,T	Steel tanks, used to treat slop oil emulsion with heat and residence time.	1. Recovered oil from separator boxes, ponds and miscellaneous sources. 2. Slop oil emulsion solids (sludge) settled on bottom (EPA K049).	1. Recovered oil piped to Crude Unit. 2. Slop oil emulsion is piped to Centrifuge Feed Tank or Slop Oil Storage Tank for sales.

WASTE STORAGE, TREATMENT, AND DISPOSAL UNITS
SHELL OIL COMPANY - WOOD RIVER, ILLINOIS

UNIT	TYPE[a]	DESCRIPTION	INPUTS (AND OUTPUTS)	DISPOSITION
Centrifuge Feed Tank	S	Steel tank.	1. Slop oil emulsion from Work Tanks. 2. Slop oil emulsion solids (sludge) settled on bottom (EPA K049).	1. Slop oil emulsion is piped to Centrifuge. 2. Sludge disposition is piped to Site 10, Solid Waste Basin.
Centrifuge	S,T		1. Slop oil emulsion from Centrifuge Feed Tank.	1. Recovered oil piped to Crude Unit. 2. Sludge is piped to Site 10, Solid Waste Basin.
Slop Oil Storage Tanks: S-8, R-8	S	Steel tank.	1. Slop oil emulsion from Work Tanks. 2. Slop oil emulsion solids (sludge) settled on bottom. 3. Compounded lube slops.	1. Slop oil emulsion is sold to outside vendor for oil recovery; this is for emulsion that cannot be centrifuged.
Aeration Basin (Mixer)	S,T	Concrete basin.	1. Oily water from API Master Box Separator. 2. Sanitary sewage from Sanitary Sewer System. 3. Spent lime sludge from water softening.	1. The three input streams are mixed by agitation. Oil is sorbed by the lime sludge. 2. The mixed waste is piped to the API Separator.
API Separator	S,T	Concrete basin.	1. Mixture of lime sludge, oily water, and sanitary sewage from Aeration Basin. 2. API Separator float; probably oil-coated spent lime and other particulates. 3. API Separator sludge (EPA #K051); probably oily lime sludge.	1. Oily water effluent piped to DAF 1. 2. API Separator sludge and float pumped to Solid Waste Basin (Site 10).
DAF 1	S,T	Concrete basin	1. Effluent from API Separator. 2. Float (EPA K048). 3. Bottoms sludge.	1. DAF effluent piped to Aerated Pond 1 of Bio-Treatment Unit. 2. DAF float and bottoms sludge pumped to Solid Waste Basin (Site 10).

WASTE STORAGE, TREATMENT, AND DISPOSAL UNITS
SHELL OIL COMPANY - WOOD RIVER, ILLINOIS

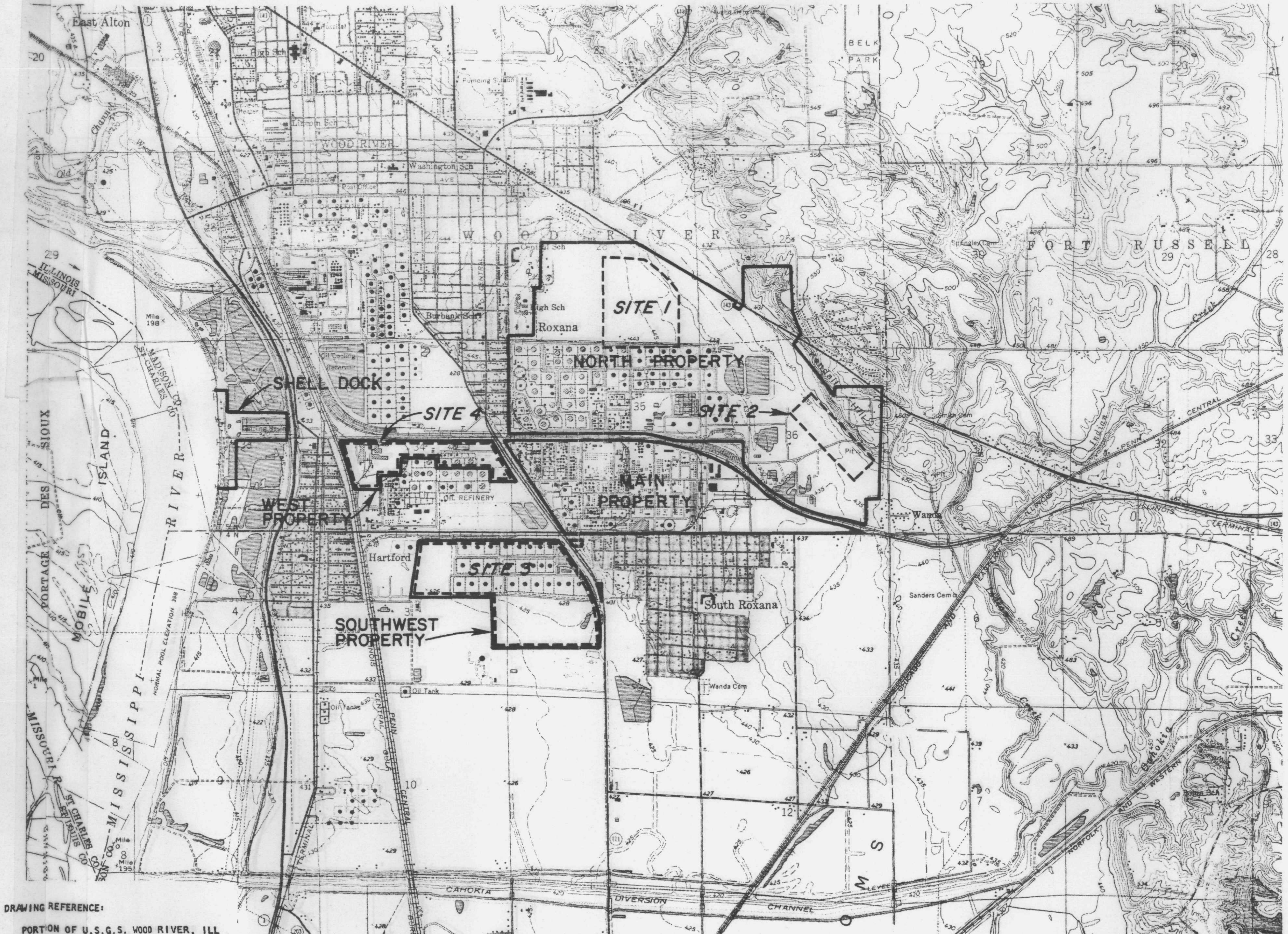
UNIT	TYPE[a]	DESCRIPTION	INPUTS (AND OUTPUTS)	DISPOSITION
Bio-Treatment Unit	S,T,D	Consists of following units: 1. Aerated Pond 1 for flow equalization. 2. Trickling Filter for biological treatment. 3. Aerated Pond 2 acting as a low solids activated sludge treatment unit. 4. DAF 2 acting as a final clarifier, separating bio-sludge for recycle and disposal. 5. Polishing Lagoons - earthen basins on the river side of flood levees. This unit probably achieves some biodegradation and sedimentation of the wastewater before discharge to the river.	1. Effluent fromm DAF 1. 2. Bio-sludges generated by Trickling Filter, Aerated Pond 2, DAF 2, and Polishing Lagoons.	1. Treated effluent from the Polishing Lagoons is discharged to Mississippi River outfall under NPDES permit. 2. Generated bio-sludges are completely recycled within the Bio-Treatment System. In the future, a waste sludge stream may be generated. 3. Settled sludges on bottoms of Polishing Lagoons are not routinely removed.

TABLE 3

EVALUATION OF SITES

PARAMETER		SITE 1	SITE 2	SITE 3	SITE 4
Geology & Soil Type		-1	+2	+1	+1
Ground-Water Hydrology		+1	+1	0	-2
Proximity to Populated Areas		-1	-1	0	-2
Topography		+2	+1	+1	+1
Flood Hazard Areas		+2	-1	-1	+1
Wetlands		+1	-1	-2	+1
Distance from the Plant		+2	0	+1	+1
	Total	6	+1	0	+1
If Distance from the Plant is eliminated as a key parameter the rating totals would be:		+4	+1	-1	-0

Sites 3 and 4 have been eliminated from further consideration (see text).



DRAWING REFERENCE:

PORTION OF U.S.G.S. WOOD RIVER, ILL QUADRANGLE, DATED 1974

LEGEND:

——— SHELL PROPERTY BOUNDARY

– – – APPROXIMATE SITE BOUNDARY

NOTES:

1. SITE BOUNDARIES ARE APPROXIMATE AND WILL BE IDENTIFIED DURING PHASE 2.
2. BORING LOCATIONS WILL BE IDENTIFIED DURING PHASE 2.

1000 0 1000 3000 5000 7000 FEET

FIGURE 1
SHELL OIL COMPANY
WOOD RIVER REFINERY
LOCATION MAP

DAMES & MOORE

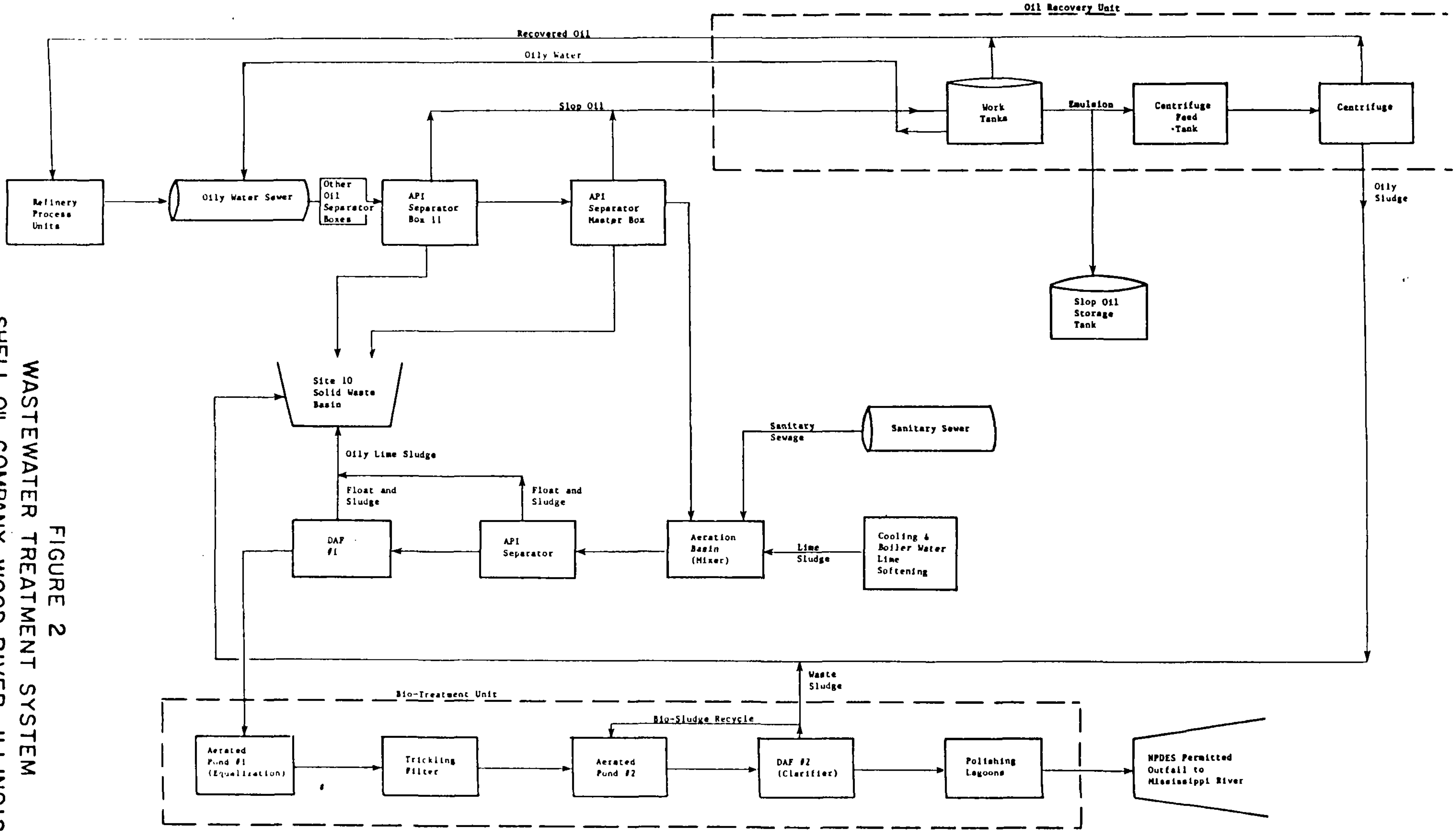


FIGURE 2
WASTEWATER TREATMENT SYSTEM
SHELL OIL COMPANY, WOOD RIVER, ILLINOIS

DAMES & MOORE

LEGEND:

GEOLOGY

WISCONSINAN AND HOLOCENE

c — CAHOKIA ALLUVIAUM
-floodplains, channels, modern rivers mostly poorly sorted sand, silt or clay and local sandy gravel

WISCONSINAN

pr — PEORIA LOESS AND ROXANA SILT
-windblown silt, local lenses of fine gravelly sand

hm — MACKINAW MEMBER OF HENRY FORMATION
-sand and gravel, generally well sorted, bedded. Terrace remnants
-former valley trains

--------- APPROXIMATE GEOLOGIC CONTACT

——— SHELL PROPERTY BOUNDARY

1000 0 1000 3000 5000 7000 FEET

DRAWING REFERENCES:

1) PORTION OF U.S.G.S. WOOD RIVER, ILL QUADRANGLE, DATED 1974
2) LINEBACK, J.A., 1979, QUATERNARY DEPOSITS OF ILLINOIS: IL. STATE GEOL. SURVEY, MAP. SCALE 1:500,000.

FIGURE 4
SURFICIAL DEPOSITS IN THE VICINITY OF THE SHELL REFINERY

DAMES & MOORE

DRAWING REFERENCES:

1) PORTION OF U.S.G.S. WOOD RIVER, ILL QUADRANGLE, DATED 1974.
2) SHELL OIL CO., 1980, WATER TABLE MAP MAY 5, 1980 DATA - WOOD RIVER REFINERY.

FIGURE 5
WATER TABLE CONTOUR MAP
MAY 5, 1980
AFTER WATER TABLE MAP BY
WILLIAM SHEPHERD, SHELL OIL COMPANY

DAMES & MOORE

LEGEND:

SURFACE WATER HYDROLOGY

- Areas of 100 year shallow flooding (1-3ft.) based on Federal Insurance Rate Map (FIRM)
- Areas of 100 year shallow flooding (1-3ft.) based on projection from FIRM
- Areas between limits of 100 year and 500 year flood; or certain areas subject to 100 year flooding with average depths less than 1 ft.
- Areas between limits of 100 year and 500 year flood; or certain areas subject to 100 year flooding with average depths less than 1 ft. based on projection from FIRM.
- SURFACE DRAINAGE DIVIDES
- SHELL PROPERTY BOUNDARY

1000 0 1000 3000 5000 7000 FEET

DRAWING REFERENCES:

1) PORTION OF U.S.G.S. WOOD RIVER, ILL QUADRANGLE, DATED 1974

FIGURE 6
SURFACE-WATER HYDROLOGY IN THE VICINITY OF THE SHELL REFINERY

DAMES & MOORE

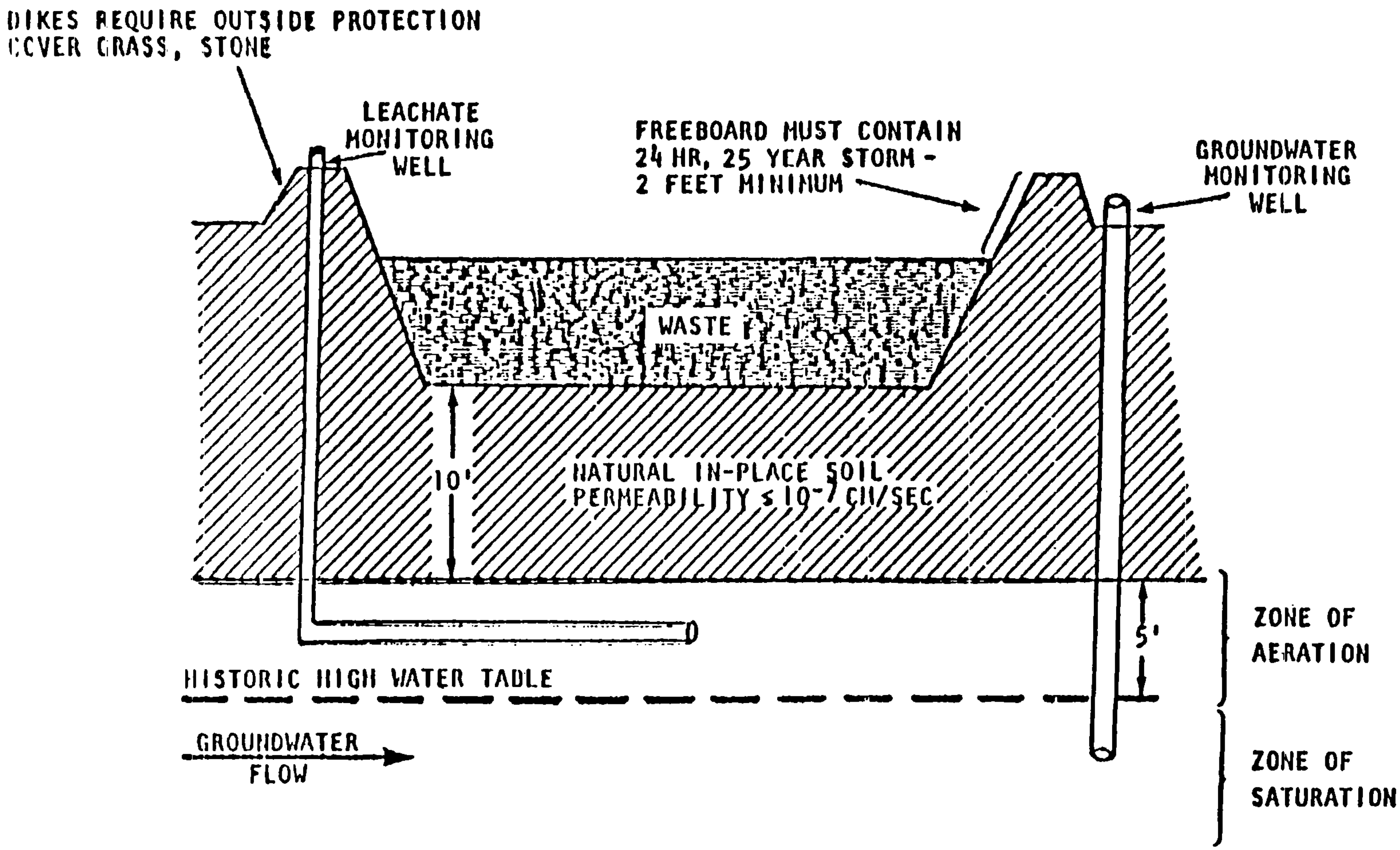


FIGURE 7
TERMINAL SURFACE STORAGE IMPOUNDMENT*
GEOLOGIC CONDITIONS EXISTING

* LANDFILL REQUIRES CLIMATIC CONDITIONS SUCH THAT EVAPORATION EXCEEDS PRECIPATATION BY 20 INCHES PER YEAR.

DAMES & MOORE

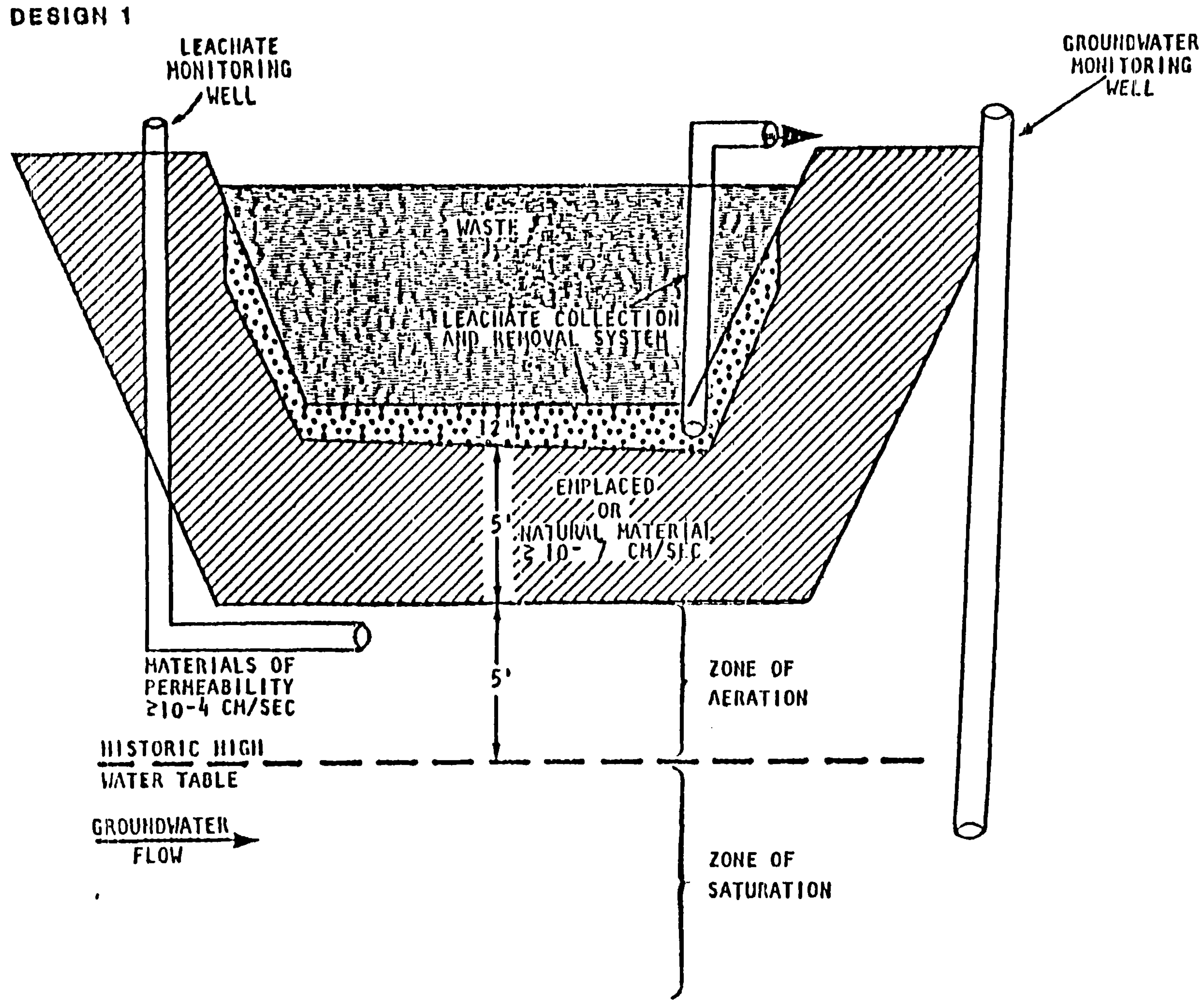


FIGURE 8
LANDFILL OR TERMINAL
SURFACE STORAGE IMPOUNDMENT-A

DAMES & MOORE

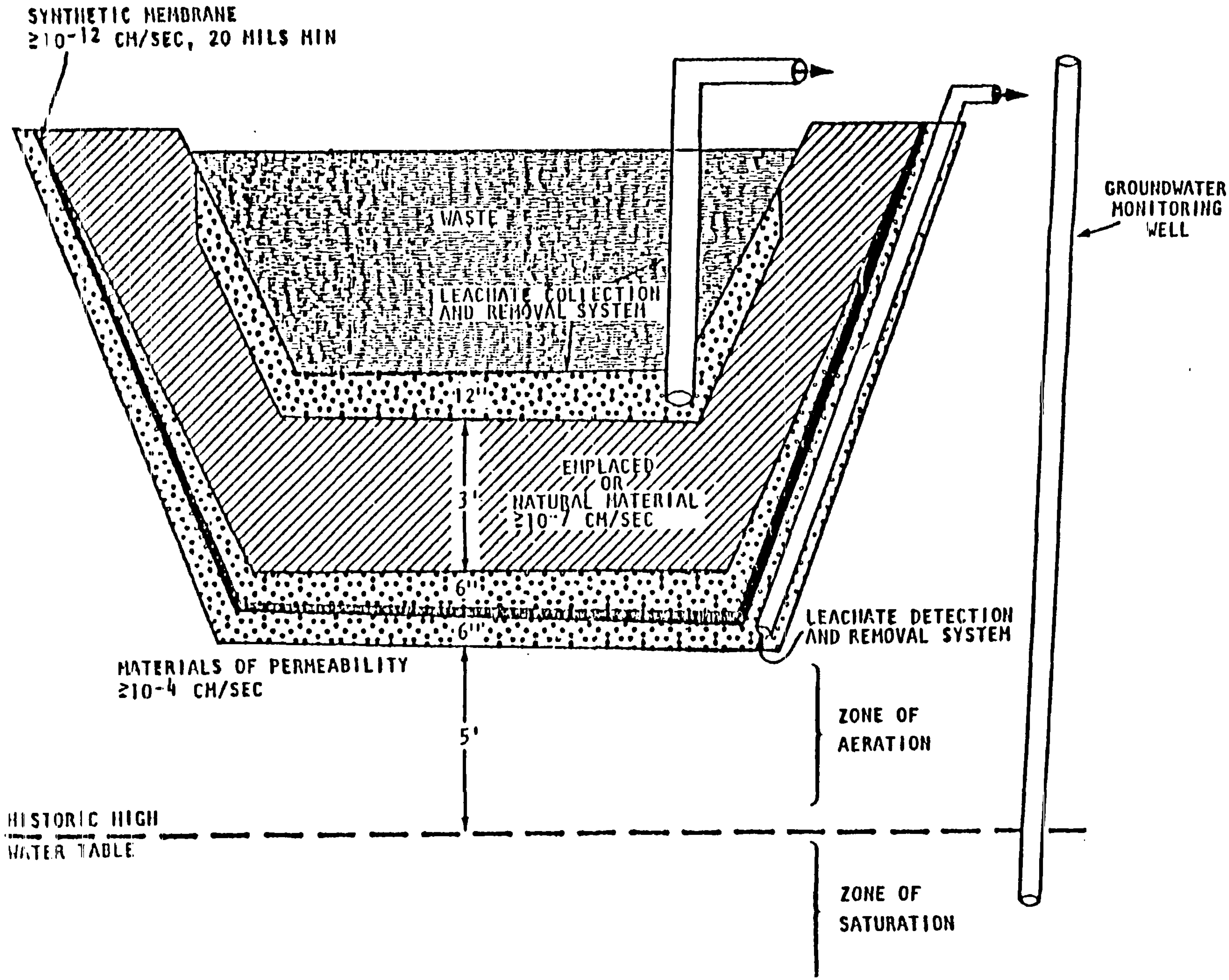


FIGURE 9
LANDFILL OR TERMINAL SURFACE STORAGE IMPOUNDMENT-B

DAMES & MOORE